



Simulation Tools for Nondestructive Evaluation

R. Bruce Thompson

Center for Nondestructive Evaluation

Iowa State University

[Outline

- Broad Technological Need
- Particular Scientific Advancement in Response to Market
- Management Factors Contributing to Success
- Summary

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[Background

- Prior to 1970, nondestructive testing had been conducted in an empirical fashion with limited predictive or analytical foundations
- The situation was changed by
 - A problem (unexpected military failures and concerns about the safety at nuclear power plants in the late 1960s)

C-5 engine pylon failure



Manufacturing defect leading to F-111 wing failure



- PLUS -

- A tool (fracture mechanics)

Research and Development Programs Established In Quantitative NDE Around the World

- United States
 - Interdisciplinary Program for Quantitative Nondestructive Evaluation (AF/DARPA)
 - EPRI NDE Center
- Europe
 - NDT Centre (Harwell, AERE, UK)
 - IZFP (Fraunhofer, Saarbrücken, Germany)
- Asia and other regions



Evolution of the Field in the United States Driven by Major Events/Concerns

1970 Serious incidents and new energy sources spark concern



Airframes

1980

1990



Jet engines

Pipelines



2000



Space shuttles



Major Phases in the Development of the Field

- Creating a core science base (1970s)
- Maturing the science base: window problems (1980s)
- Utilizing the science base (1990s)
 - competitiveness driven applications (reliability)
 - commercial aviation (safety)
 - infrastructure (safety)
- The implementation of the science base has been enabled by the I/UCRC which engaged major companies in the further development and application of the technology (established 1985)

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[Simulation Tools

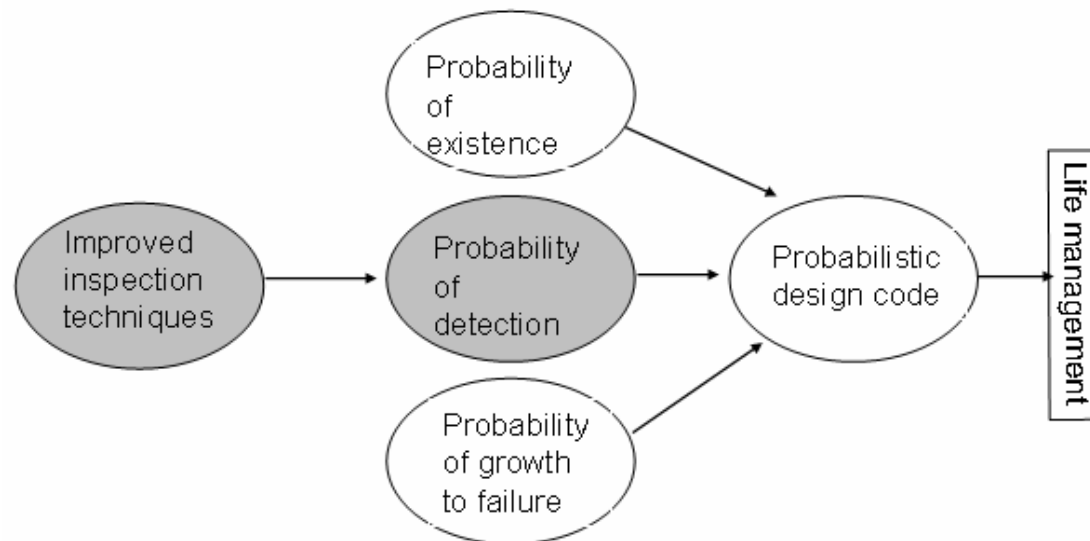
- The continued development of physics-based models of inspection processes and their incorporation in simulation tools is one example of how the I/UCRC is making a very positive economic impact on industry.

[The Role of NDE

- An enabling technology that responds to the needs of society
 - goal: greatest safety and reliability of structural and other systems at the lowest cost
- Economics is always an issue
 - how much will
 - society pay for increased public safety?
 - business/government pay for increased reliability?

Role of Simulations

- Simulation tools reduce the time and cost (samples and measurements) to perform important engineering functions such as test development and evaluation
- Simulations are playing an increasing role in the highlighted life management functions

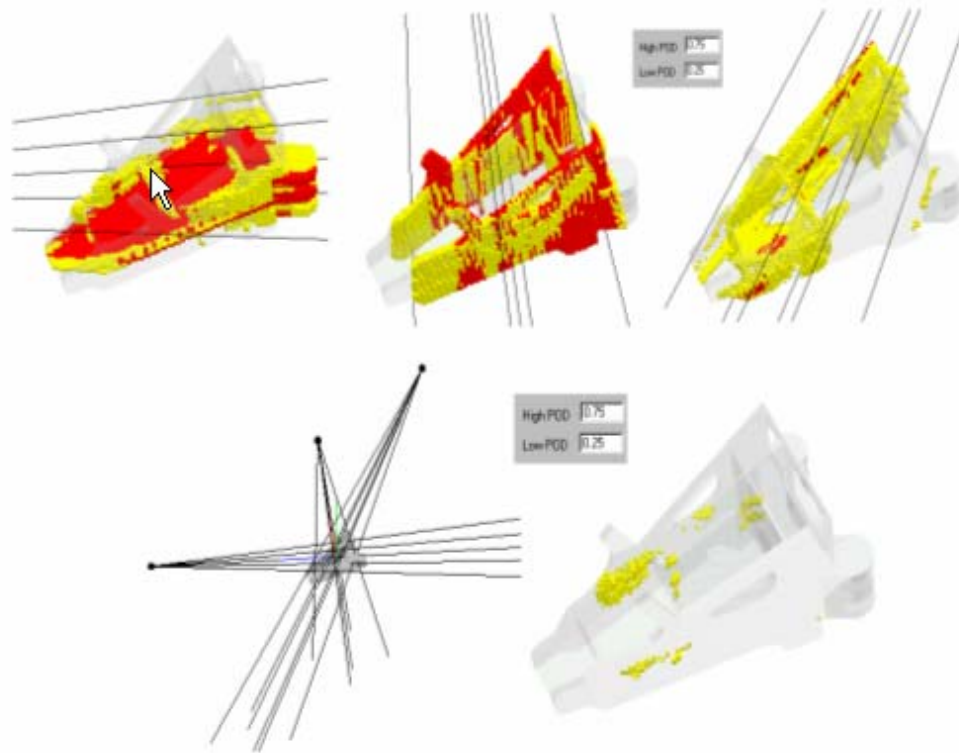


[Simulator Components

- A simulator consists of the following
 - Graphical user interface
 - Test piece geometrical representation
 - Flaw geometrical representation
 - Input signal generation
 - Signal and test piece interaction computations
 - Detector response computations
 - Post processing of synthetic data
- Both a rigorous understanding of the physics and attention to making tools user-friendly are required.

An X-Ray Example Detectability Maps

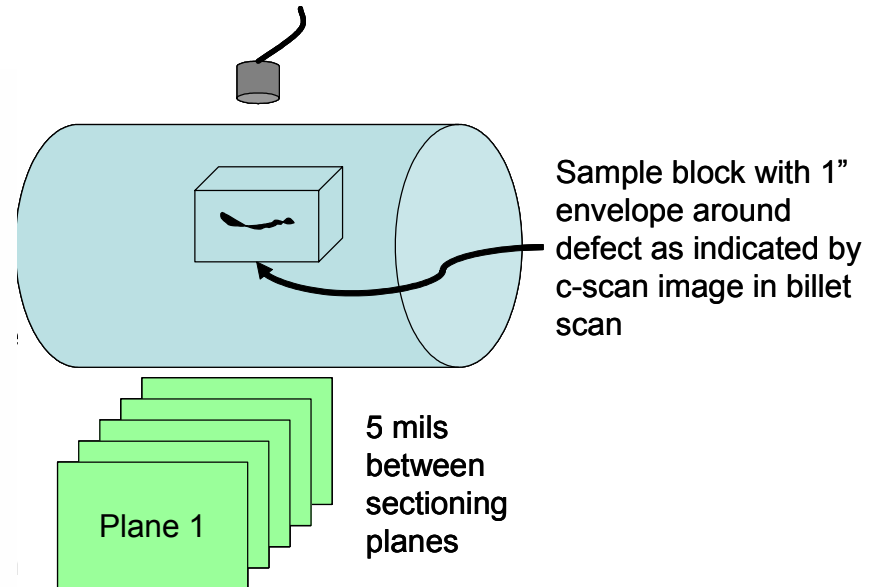
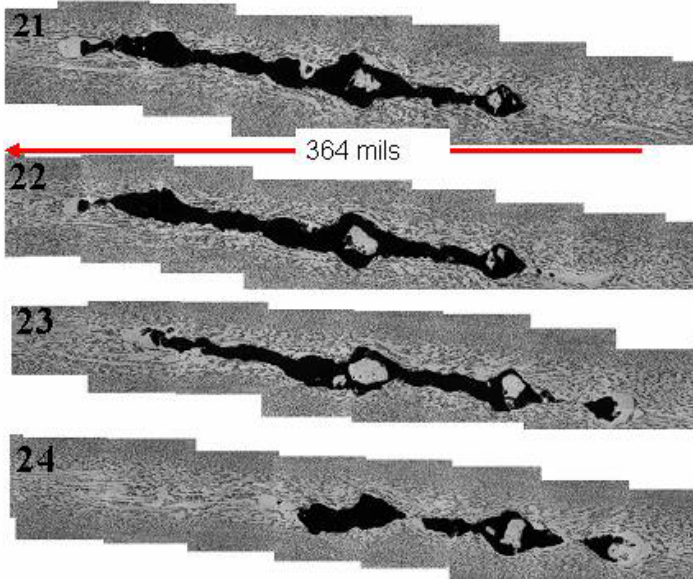
- Rapidly assessing the effect of sample orientation



An Ultrasonic Example Simulation of Signal Strengths

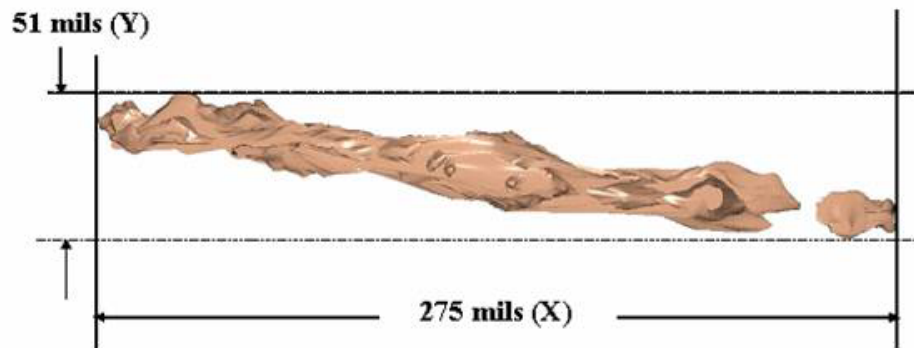
- Assessing the effects of flaw morphology

B1AW2 - D



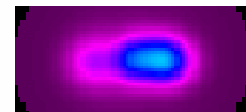
Use of UT Simulations to Understand Effects of Flaw Morphology on Signal Strength

Dimensions of B1AW2 – D:



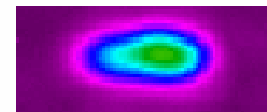
Side 1

Model



Attenuation=18dB
peak amplitude = 231 mv
deviation=-34% or -3.56 dB

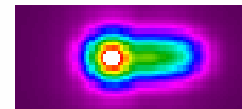
Experiment



Attenuation=18dB
peak amplitude = 348 mv

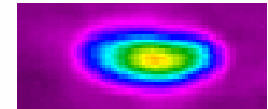
Side 3

Model



Attenuation=12dB
peak amplitude=564 mv
deviation=29% or 2.20 dB

Experiment



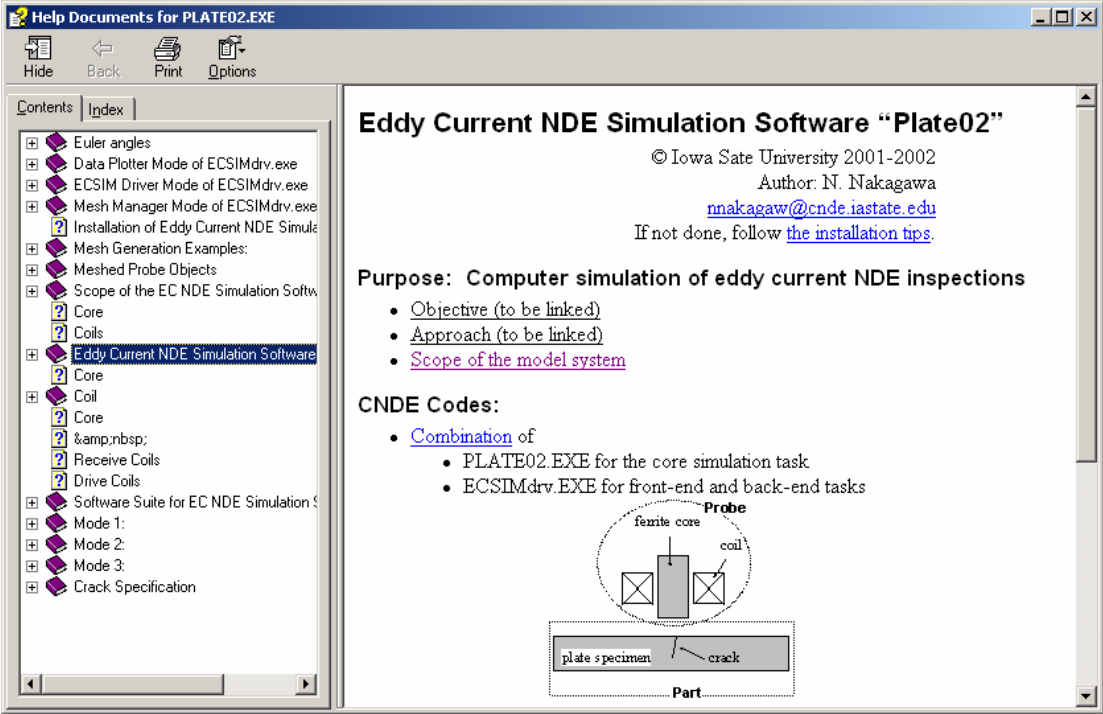
Attenuation=12dB
peak amplitude=438 mv

Experiment image: 70(H) x 30(V) @10 mils

Model image: 71(H) x 31(V) @10 mils

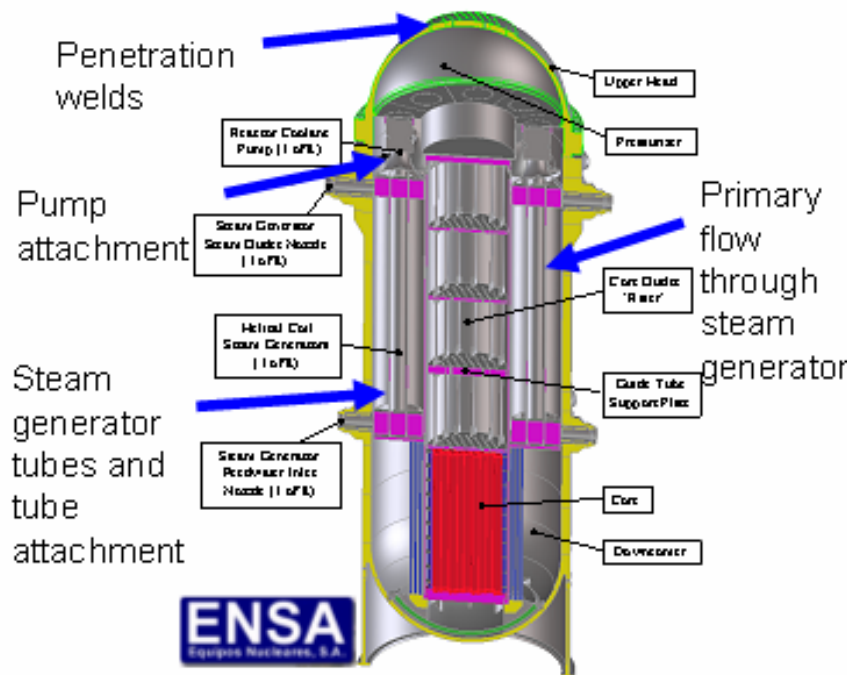
[An EC Example "Plate02"

- In order to capture their potential benefits, tools must be user friendly



A Forward Looking Example Assistance in the Design of Advanced Reactors

- NERI Project: On-line NDE for integral reactor coolant system



Project is to develop conceptual on-line NDE systems that can be built into next-generation power system designs

- For monitoring system integrity while reactor is in operation
- Collaborative project working with an industrial partner.

Examples of Sponsor Usage

- A major land-based gas turbine manufacturer saved \$500K per year in avoiding the manufacture of curvature correction blocks.
- Under FAA support, a consortium of aircraft engine companies are using these tools to design the ultrasonic probes used to inspect billet and forging materials for critical defects.
- A fourth engine company is using the x-ray simulator in the screening of proposed inspection procedures, avoiding unnecessary and expensive experimental tests.

Examples of Sponsor Usage (Continued)

- One aerospace company has estimated that a particular ultrasonic application saved them \$1M in the first year alone and is investing a like amount at CNDE to develop other possibilities.
- Eddy current simulators are being used in the nuclear, aircraft engine and general aviation industries to evaluate the capabilities of a wide range of

[The Way Forward: Commercialization

- A small business, NDE Technologies, was formed in 1997 to commercialize the technology
 - X-ray simulation software on the market
 - Negotiations under way with respect to simulation tools for other modalities

The Way Forward: Formation of Working Group on Computational NDE for Modeling Probability of Detection

- AF, FAA, and NASA support
- Possibilities recognized
 - Replace, to a large degree, costly and time-consuming experimental programs for prediction of NDE reliability
 - Improve component design and definition of the life cycle
 - Optimize and validate NDE hardware and procedures
 - Develop and quantify improved physical calibration standards
 - Provide an NDE simulator for training and education
- Initial goal
 - To develop, validate and demonstrate a selected set of modeling capabilities with initial focus on a single technique (ultrasonics?) for NDE reliability. These modeling capabilities will be broad enough in scope to serve as a persuasive demonstration of the great value of modeling of NDE reliability.

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Role of the I/UCRC Program

Major Programs Enabled by I/UCRC

- Creating a core science base (1970s)
 - AF/DARPA
- Maturing the science base (1980s)
 - AF/DARPA (until 1989)
 - I/UCRC (1985 start)
 - Research, development and technology transfer
 - Development of enhanced educational materials
 - Simulation tools to empower NDE engineers to hold a full seat at the systems engineering table
 - Industrial funding of projects in response to proprietary needs

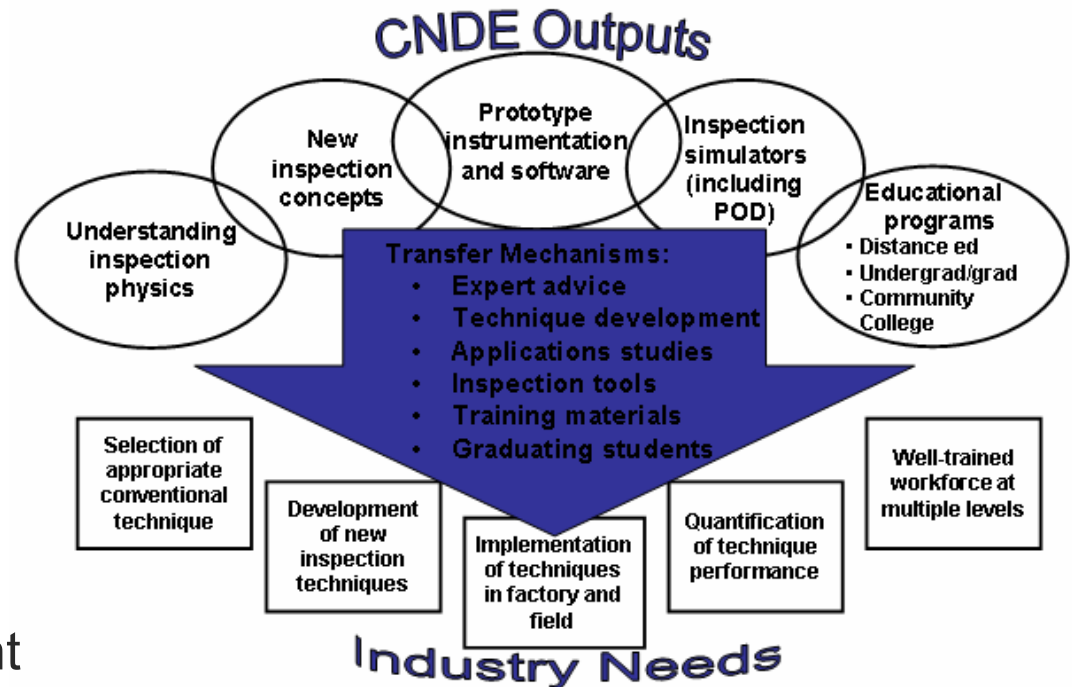
Role of the I/UCRC Program

Major Programs Enabled by I/UCRC (Cont.)

- Utilizing the science base
 - NIST – NDE simulation tools for design (1989-1998)
 - FAA – Commercial aviation (airframes and engines) (1989-present)
 - NASA – Future aerospace systems (2001-present)
 - AF – Military aircraft (2002-present)
 - Proprietary Programs – Numerous company specific needs

Benefits

- CNDE
 - A critical mass of scientists, engineers and students dedicated to solving the NDE problems of industry
- Benefit to industry
 - A shared, cost-effective corporate research laboratory with functions of basic research, development and technology transfer
- Coupling of CNDE and Industry



[Benefits

CNDE sponsoring companies have:

- Opportunity to guide the directions of generic, pre-competitive research that will provide the foundation for industrial technologies
 - Biannual formal Industrial Advisory Board meeting
 - More frequent informal contacts
- Immediate access to the results of that work
 - Expert advise
 - Biannual technical reviews
 - Short courses

[Benefits

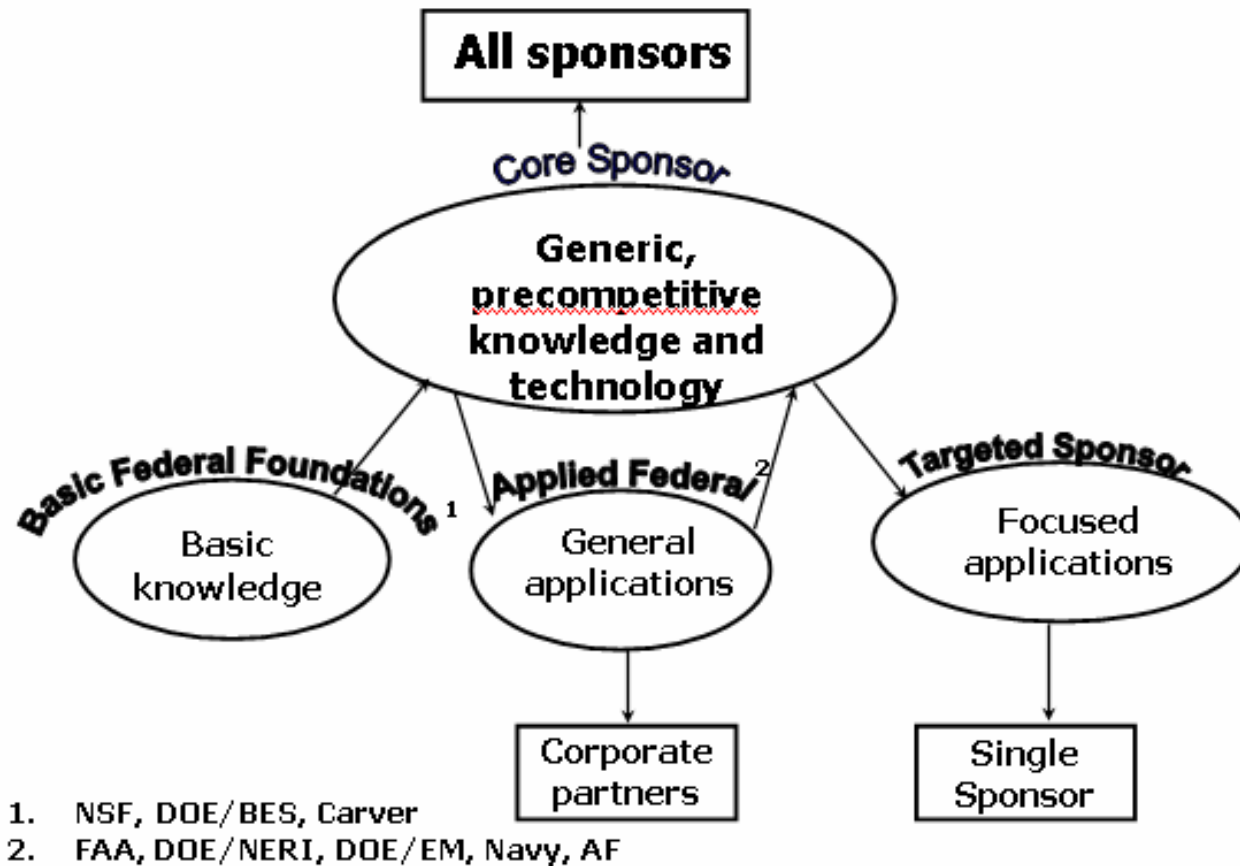
- Outputs include
 - Inspection physics
 - New inspection concepts
 - Prototype instrumentation and software
 - Inspection simulations
 - Educational programs
 - Students
 - Early contact, internships, and potential employees
- A window to worldwide NDE advances
 - Attendance at annual meeting with proceedings
 - Personal contacts

[Benefits

CNDE sponsoring companies also have available:

- A partner that seeks funding when possible to further advance items of particular common interest
 - Various government programs
 - CASR and ETC (FAA)
 - Advanced Reactor Concepts (DOE)
 - Advanced Technological Education (NSF)
 - A skilled and committed team member to support applying generic results to specific company problems
 - Government funded
 - Corporate funded
 - Can work within proprietary framework

Role of Different Funding Sources in Satisfying Sponsor Needs



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- Technological need
 - Nondestructive techniques to provide quantitative flaw information
- Scientific advance
 - Simulation tools incorporating forefront understanding of measurement physics in user-friendly formats
- Economic motivation
 - Reduce time and cost of empirical approaches
- Management keys
 - I/U CRC provides a focal point for industry to pool resources and guide the developments so that they will have the greatest impact